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# Full waveform inversion for upper-mantle structure in the Australasian region based on the spectral-element and adjoint methods

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We present results from a full seismic waveform tomography for upper-mantle structure in the Australasian region.

The tomographic images are based on high-quality data collected over the past 15 years at several temporary arrays and permanent stations. Fundamental- and higher-mode surface waves as well as S body waves and multiple reflections are used.

The centrepieces of our methodology are envelope and phase misfits computed from time-frequency transforms of the seismograms. They allow us (1) to extract a large amount of robust information that is quasi-linearly related to Earth structure, (2) to separate phase and amplitude information and (3) to measure time- and frequency-dependent misfits for all types of elastic waves including interfering phases that are common at shorter epicentral distances. These characteristics make the envelope and phase misfits well-suited for high-resolution full waveform tomography.

We derive Fréchet kernels for the envelope and phase misfits using the adjoint method in conjunction with a recently developed and highly efficient spectral-element code that operates in a spherical section. The tomographic problem itself is solved by iteratively minimising the phase and – to a lesser extent – the envelope misfit. To ensure the convergence of the misfit minimisation we use a smoothed ray-tomographic image of the Australasian region. In the course of the iteration we decrease the dominant period from 100 s to 50 s, and we reach acceptable results after 10 to 15 iterations.

In the upper 100 km of our current tomographic model we observe S wave speed variations of $\pm 15$ % that reduce to $\pm 3.5$ % at 500 km depth where the resolution starts to become poor. The principal tectonic features of the Australasian region, are clearly visible, but also small-scale variations within them can be distinguished. Resolution tests indicate that lateral S wave speed variations as small as $2^o \times 2^o$ can be detected reliably in central and eastern Australia and in the Coral and Tasman Seas - despite the relatively long periods used.